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ABSTRACT

As the nation pursues the goal of becoming first in the world in science achievement among students, many are advocating an instructional approach that emphasizes activities and learning by doing. Instructional approaches in science education that involve activity and direct experience have become collectively known as hands-on science. This document presents 10 questions frequently asked by elementary and middle school teachers about hands-on science teaching and learning. Each question is followed by answers in three categories: responses from classroom teachers, thoughts from the curriculum and activity developers, and notes from the educational research and literature. The questions considered in this document are: (1) What is hands-on learning, and is it just a fad? (2) What are the benefits of hands-on learning? How do I justify a hands-on approach? (3) How does a hands-on science approach fit into a textbook-centered science program? (4) How can practicing teachers gain experience with hands-on methods? (5) Where do I find resources to develop hands-on activities? (6) How is hands-on learning evaluated? (7) What are some strategies for helping students work in groups? (8) How does or should the use of hands-on materials vary with age of students? (9) Hands-on science can be expensive. How do I get materials and equipment? (10) Where do you keep materials and equipment once you get them? Final comments note that different educators have different concerns related to each question, that none are as simple as they may first appear, and that the answers offered in this booklet will soon have to be supplemented by questions and answers more immediately related to local needs and priorities. (70 references) (PR)

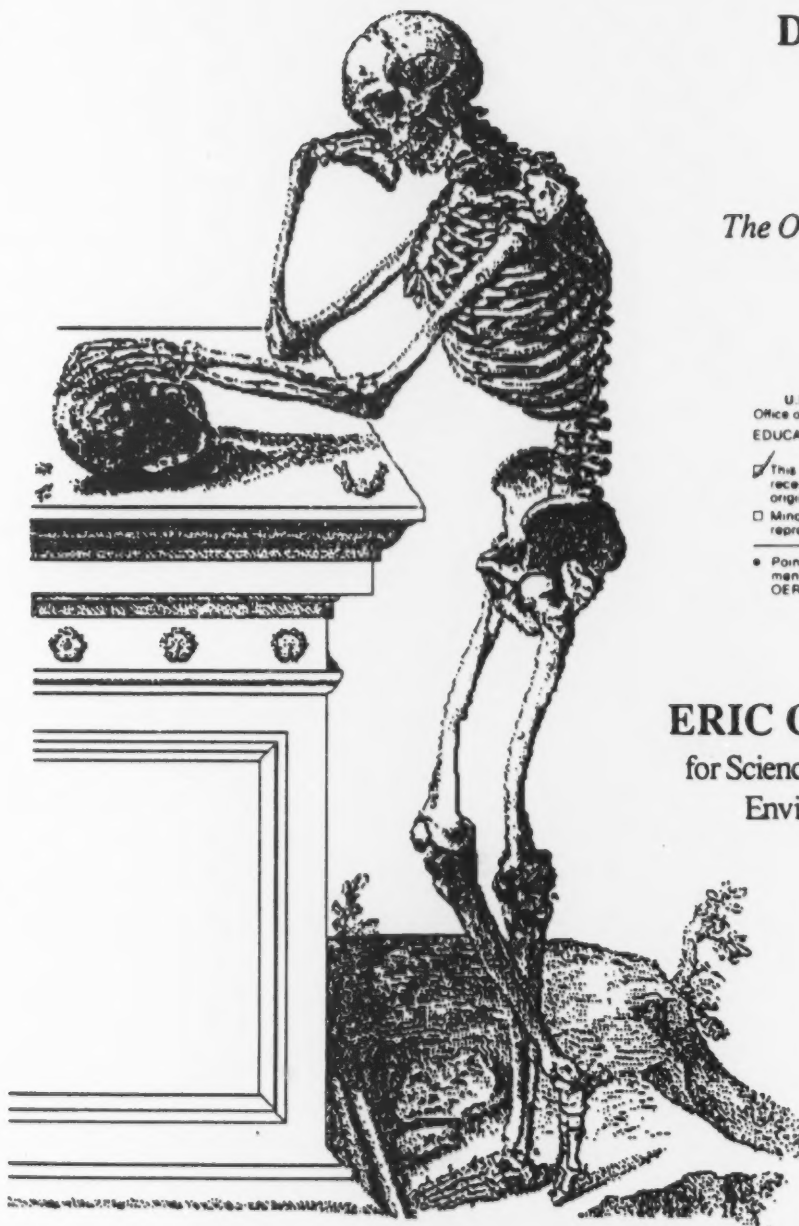
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Hands-On Approaches to Science Teaching

Questions and Answers from
the Field and Research

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Preface

This document presents answers to frequently asked questions about hands-on approaches to science teaching and learning. The questions were formulated by speaking with teachers and people who work with teachers on a regular basis to improve classroom practice. Variations of the questions are frequently asked by both experienced and novice teachers. Though not a comprehensive or definitive work on hands-on approaches to science teaching, this compilation of questions and answers is intended as a resource for teachers, administrators, parents, and curriculum specialists who are attempting to foster improved science teaching and learning in their schools. Think of this as a "briefing document," a summary of information that will help hands-on advocates focus on the key issues and provide sufficient background to get practitioners started down a path of instructional reform.

The authors view this work as the beginning of a professional dialog that will lead to revised editions of this document and a heightened awareness of the issues associated with hands-on approaches to science teaching. Readers are invited to participate in the dialog by submitting their answers to the questions posed here or by suggesting additional questions that need answering. We will carefully consider each submission for inclusion in the next edition of this publication, to be developed and released as funding becomes available. All contributions will be appropriately acknowledged.

Send contributions or inquiries to: David L. Haury, ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1200 Chambers Road, Room 310, Columbus, OH 43212.

Acknowledgments

Many people contributed to the development of this document; some offered written or oral responses to the questions we asked, and others suggested questions to ask, people to contact, and materials to review. We have not included in this document every question or answer that we received, but we read them all and tried to capture the full range of perspectives and ideas submitted. However, we did not consolidate answers. We chose to let contributors present their ideas in their own words, so you will find individuals identified along with their remarks in the pages that follow. Our thanks to each of them for their help, in some cases on very short notice.

Some very helpful individuals are not identified in the pages that follow, so we would like to acknowledge their help here. Dr. Norman Lederman at Oregon State University helped us identify practitioners in the Northwest; Dr. Anita Greenwood at the University of Massachusetts Lowell helped us identify practitioners in the Northeast; Betsy Feldkamp at The Ohio State University helped us identify practitioners in the Midwest; and Dr. Carole Kubota at the University of Washington helped us formulate several of the questions posed in the pages that follow. Each of these individuals is associated with programs that emphasize hands-on approaches to learning, and they have worked with many teachers to promote professional growth in science teaching. Their voices of experience were invaluable to our work, and we thank them for their help. Finally, Linda Milbourne at the ERIC Clearinghouse for Science, Mathematics, and Environmental Education provided the final proofreading of the manuscript, saving us from many grammatical embarrassments. Thanks, Linda, for your attention to detail.

Thanks, too, to everyone who contributes to the cause as a result of reading this document. Please notice that it is not protected by copyright, so you may make as many copies as you wish in your efforts to improve science teaching. Let us know how you do, and remember to share the insights that you gain as you attempt change in your spheres of influence.
DLH & PR.

Introduction

As the nation pursues the goal of becoming first in the world in science achievement among students (U.S. Department of Education, 1991), many are advocating an instructional approach that emphasizes activities and learning by doing. Many pushing for reform of science teaching say, "Young people can learn most readily about things that are tangible and directly accessible to their senses....With experience, they grow in their ability to understand abstract concepts, manipulate symbols, reason logically, and generalize" (Rutherford & Ahlgren, 1990, p. 186). Almost all the national reports on the conditions of teaching and learning in schools call for, "More active learning for students and less passivity; more hands-on, direct opportunities to 'make meaning'" (Schmieder & Michael-Dyer, 1991). In classrooms where students are encouraged to *make meaning*, they are generally involved in "developing and restructuring [their] knowledge schemes through experiences with phenomena, through exploratory talk and teacher intervention" (Driver, 1989). Indeed, research findings indicate that, "students are likely to begin to understand the natural world if they work directly with natural phenomena, using their senses to observe and using instruments to extend the power of their senses" (National Science Board, 1991, p. 27).

Instructional approaches that involve activity and direct experiences with natural phenomena have become collectively known as *hands-on science*, "any...activity that allows the student to handle, manipulate or observe a scientific process" (Lumpe & Oliver, 1991). Unfortunately, the use of hands-on activities is far less frequent than lecture and discussion (Weiss, 1987). Most American schools offer traditional instruction in science, with relatively few schools tailoring curricula for a hands-on approach (Howe, Blosser, Helgeson, & Warren, 1990). In a national longitudinal study, 41% of the eighth grade students were reported to be in classrooms where experiments were seldom conducted (National Science Board, 1991, p. 27). The findings perhaps reflect teachers' uncertainty, discomfort, or limited backgrounds with experiential approaches to science teaching, coupled with a cultivated dependency on textbooks (Morey, 1990). According to data from a 1987/88 Schools and Staffing Survey, "fewer than half of all middle school teachers of biological sciences and only about one-fifth of teachers of physical sciences felt they were teaching the subject for which they were best qualified" (National Science Board, 1991, p. 31). In short, teachers have questions and concerns about science teaching, and many seem reluctant to engage students in "hands-on" learning.

In the pages that follow, we present ten questions that teachers frequently ask about hands-on teaching and learning, and we provide three different types of answers to each question, representing the perspectives of classroom teachers, curriculum developers, and educational

researchers and theorists. The questions have come directly from teachers themselves and teacher educators, people who work regularly with classroom teachers and know the questions they ask. In an attempt to be direct and clear, we have presented the answers as discrete responses, with no attempt to force consensus or an internally consistent message. Rather, you will hear individual voices representing the broad range of teachers and specialists in science education. Responses from the research literature are necessarily abbreviated, but full citations are provided for each informational *nugget*. Please note that the questions are arranged in what seems like a logical sequence to the authors; they are not arranged according to any ranking or weighting process based on level of concern.

Questions and Answers

1. *What is hands-on learning, and is it just a fad?*

Teacher's Response



Hands-on learning is learning by doing. To even imply that it is a fad is to ignore what has been taking place in education, both formal and informal, for years. Vocational education has always understood that if you want someone to learn to repair an automobile, you need an automobile to repair. If you want to teach someone to cook, you put them in a kitchen. Whoever heard of teaching someone to swim in a traditional classroom? Likewise, I do believe we are learning that in order to truly teach science, we must "do" science.

Jeff G. Brodie, fifth and sixth grade teacher, East Side Elementary, Edinburgh, IN

Developers' Thoughts



There is no doubt that there is more emphasis on hands-on materials than in the recent past. That does not mean, however, that the hands-on science activity ever passed away. Furthermore, good science programs cannot exist without hands-on; I do not think it will ever pass away. I do think that we must continue to emphasize the necessity of hands-on in science curriculum, and I truly hope we can keep the hands-on component at a high level.

Jerald A. Tunheim, Project SMILE (Science Manipulatives in the Learning Environment), Dakota State University, Madison, SD



Programs that are fun and clearly result in developing the curiosity, competency, creativity and caring of learners must, by definition, represent appropriate educational practices. The value of such programs does not change, no matter when or what they are called.

Julie Gantcher, Pablo Python Looks at Animals, Bronx Zoo Education Department

Notes from the literature



"Hands-on science is defined as any science lab activity that allows the student to handle, manipulate or observe a scientific process" (Lumpe & Oliver, 1991). Hands-on teaching can be differentiated from lectures and demonstrations by the central criterion that students interact with materials to make observations, but the approach involves more than mere activity. The assumption is that direct experiences with natural phenomena will provoke

curiosity and thinking, so, "recently, a new twist has been added, and the topic is called Hands-on/Minds-on science" (Lumpe & Oliver, 1991).

The historical roots of hands-on science teaching



Hands-on science in America descended from object teaching which was developed from Pestalozzian theory (Parker, 1919).



The Committee of Ten (National Education Association, 1893) was instrumental in securing a permanent place for science in the American school curriculum. The science committees repeatedly stressed the importance of object manipulation by students. The Physics, Chemistry and Astronomy Committee recommended "That the study of simple natural phenomena be introduced into the elementary schools and that this study, so far as practicable, be pursued by means of experiments carried on by the pupil" (National Education Association, 1893, p. 118). They added, "The study of books is well enough and undoubtedly important, but the study of things and of phenomena by direct contact must not be neglected" (National Education Association, 1893, p.119).



The Natural History Committee of the Committee of Ten concurred on the importance of direct concrete experience. They resolved that "the study of natural history in both the elementary school and the high school should be by direct observational study with the specimens in the hands of each pupil, and that in the work below the high school no text-book should be used" (National Education Association, 1893, p. 141).



"In more recent times, almost all the major science curriculum developments of the 1960s and early 1970s promoted hands-on practical work as an enjoyable and effective form of learning" (Hodson, 1990).



"Imitating the work of the scientists in investigating the natural world, usually in the laboratory, is found in all the new curricula. Whether it is called inquiry, scientific process, or problem-solving, each curricula group espoused the virtues of "hands-on" experiences to gain greater insights into the basic concepts of science" (Welch, 1979). These curriculum projects were tested and revised and provide a major impetus for current hands-on learning initiatives.



Hands-on learning can be thought of as comprising three different dimensions: the inquiry dimension, the structure dimension, and the experimental dimension. In inquiry learning, the student uses activities to make discoveries. The structure dimension refers to the amount of guidance given to the student. If each step is detailed, this is known as a cookbook style lab. These types of activities do not increase a student's problem solving abilities. The third dimension is the experimental dimension which involves the aspect of proving a discovery, usually through the use of a controlled experiment (Lumpe & Oliver, 1991).

2. *What are the benefits of hands-on learning? How do I justify a hands-on approach?*

Teachers' Responses



Students in a hands-on science program will remember the material better, feel a sense of accomplishment when the task is completed, and be able to transfer that experience easier to other learning situations. When more than one method of learning is accessed as in hands-on learning, the information has a better chance of being stored in the memory for useful retrieval. Students who have difficulty in the learning arena for reasons of ESL barriers, auditory deficiencies, or behavioral interference can be found to be on task more often because they are PART OF the learning process and not just spectators.

Justifying why I would use hands-on science is based on all the research and methods studies that are current. They support the notion of multi-faceted bombardment of information and experiences so that the retention level is improved. Students who are involved in labs and activities are empowered in their own learning process.

Mary Wieser, French Prairie Middle School, Woodburn, OR



The single most important benefit to me is that although it requires a great deal of preparation time, once a system is developed, hands-on teaching makes teaching fun. If the kids are learning and having fun doing it, then I am having fun at my job, and I am a happier person overall.

Jeff G. Brodie, fifth and sixth grade teacher, East Side Elementary, Edinburgh, IN

Developer's Thoughts



If students are not doing hands-on science, they are not doing science. Science is a process and if students are not actively engaged in the process, they are not doing science. Most science classes in elementary school teach the vocabulary of science and nothing else.

Study after study has shown the value of hands-on learning. Students are motivated, they learn more, even their reading skills improve. How can you justify not doing hands-on science?

Edwin, J.C. Sobey, National Invention Center, Akron, OH

Notes from the literature



Hands-on learning has been shown to increase learning and achievement in science content (Mattheis & Nakayama, 1988; Brooks, 1988; Saunders & Shepardson, 1984; Bredderman, 1982).



Research indicates that activity-based science can improve students' attitudes toward science (Rowland, 1990; Kyle, et al., 1988; Jaus, 1977; Kyle et al., 1985).



Evidence clearly indicates that hands-on activities increase skill proficiency in processes of science, especially laboratory skills and specific science process skills, such as graphing and interpreting data (Mattheis & Nakayama, 1988).



Bredderman (1982) synthesized 57 research findings involving 13,000 students on the effects of three major activity-based elementary science programs developed with National Science Foundation support: Elementary Science Study (ESS), Science-A Process Approach (SAPA), and The Science Curriculum Improvement Study (SCIS). Students in these programs scored an average of 20 percentile units higher on science process tests than students in conventional programs.



For both process skills and science content, academically or economically disadvantaged students gained the most from activity-based programs (Bredderman, 1982).



Hands-on learning in science has been shown to help in the development of language (Bredderman, 1982; Quinn & Kessler, 1976; Huff, 1971) and reading (Bredderman, 1982; Morgan et al., 1977; Willman, 1978).



Participation in science inquiry lessons facilitated development of both classification and oral communication skills of bilingual Mexican American third grade students (Rodriguez & Bethel, 1983).



In analyzing the literature, Barufaldi and Swift (1977) concluded that, "a definite trend emerges that science experience enhances reading readiness skills and oral communication skills among children."



Activity-centered classrooms encourage student creativity in problem solving, promote student independence, and help low ability students overcome initial handicaps (Shymansky & Penick, 1981).



"Seen only as a laundry list of theorems in a workbook, science can be a bore. But as a 'hands-on' adventure guided by a knowledgeable teacher, it can sweep children up in the excitement of discovery. Taught by the regular classroom teacher, it can illustrate the point that science is for everyone - not just scientists" (William J. Bennett (as U.S. Secretary of Education), 1986, p. 27).

3. *How does a hands-on science approach fit into a textbook-centered science program?*

Changing an approach to science teaching can be difficult because many science teachers are expected to cover a great deal of content material. Furthermore, many teachers feel trapped by pressures to prepare students for examinations (Martens, 1992).

Teacher's Response



The science textbook serves as a springboard for instruction and learning in my sixth grade classroom. Hands-on learning activities are used to reinforce and extend what my students have read in the text and what they have learned through class discussions. To foster curiosity and create motivation I might introduce a new unit by using a hands-on learning activity. At the completion of a chapter or unit these activities are useful in helping students establish the relationship of concepts and synthesize their knowledge. The teaching of lab skills, problem solving strategies and group learning skills can be easily incorporated into the learning activity.

Hands-on learning activities offer opportunities for active participation and concrete learning experiences which support the learning styles of early adolescents. The enthusiasm for lab days in my classroom has a positive effect on the attitudes my students have for science. The ability for me to interact with individual students during the hands-on learning activity enhances my effectiveness as a teacher. I feel using the textbook in conjunction with the hands-on learning approach provides a successful learning environment in my classroom.

Lynn Reid, Sells Middle School, Dublin, OH

Developer's Thoughts



A text-centered science program is anathema to good educators. The text exists to provide background information for use before and after hands-on activities, if the teacher is creative and resourceful. The teacher who is insecure, lazy, or inexperienced does not use activities, and the text is the curriculum. The good teacher seeks out activities to complement the text and more fully illustrate the concepts, to give local examples of the big picture, and to keep students interested in the subject. Text teaching is easy, organized, and disciplined, with predictable results (boredom and test anxiety). Teaching with hands-on activities is demanding, hectic, noisy, and sometimes unpredictable, but everyone is involved, eager, and active, and participants remember what they have done. Activities energize, localize, and dramatize science. I never saw a textbook do that.

Rosanne W. Fortner, The Ohio State University School of Natural Resources, producer of Ohio Sea Grant Education materials and Project JASON curriculum activities

Notes from the literature



A textbook-centered program can be augmented with a hands-on component to integrate *right brain* and *left brain* functioning in improving achievement and attitude (Hider & Rice, 1986).



Lack of time to teach hands-on science is a frequently mentioned obstacle (Tilgner, 1990; Morey, 1990). This is compounded by the tendency for teachers to want to "cover the textbook." According to a district science supervisor, "In all elementary schools, once you buy a text, it doesn't matter what the state or the district says" (about what is actually required); teachers try to cover the entire book (Martens, 1992, p. 154). To create time for hands-on instruction it is important for teachers to decide the major concepts to be taught and use hands-on activities to help achieve these goals.

4. *How can practicing teachers gain experience with hands-on methods?*

Many teachers are concerned with their limited backgrounds in science (Tilgner, 1990; Symington & Osborne, 1983), and a lack of adequate preparation becomes an obstacle to teachers in implementing science programs (Morey, 1990). Most teachers report a need for help in learning new teaching methods and obtaining information about instructional materials (Finan, 1990).

Teachers' Responses



Gaining experience with the hands-on approach is critical to feeling comfortable with this teaching strategy. Ideally, this experience would be obtained before exposing students to hands-on lessons. One way I continue to be introduced to hands-on ideas is by annually attending both our statewide science conference and the regional NSTA conference. Having funding provided is great, but even if that can't be secured, it is well worth the expense. A wealth of ideas in the form of workshops and presentations are included and are often presented in such a way that you participate in the activities, thereby gaining that valuable experience. Additional avenues for this experience include summer workshops or classes, peer coaching, and just diving in with your students using the multitude of resources available focusing on hands-on activities.

Jeff Gunn, Cheldelin Middle School, Corvallis, OR



There are several ways teachers can gain experience with the hands-on approach. 1) Watch other teachers in your building who use this method. 2) Talk to teachers who use activities or teach hands-on science. Many times you can get ideas on activities, materials, classroom management and resources that can ease your way in to this approach. 3) Find activities that correlate with a concept you are currently teaching. Try the activity and observe the students' reactions and their knowledge of the concept after the activity. 4) Go to workshops and inservice activities that promote the use of hands-on. Cooperative learning workshops would also encourage implementation.

Elizabeth A. Henline, Mt. Orab Elementary, Mt. Orab, OH

Developer's Thoughts

States frequently offer a wide variety of ways for teachers to gain experience in the hands-on approach. Though the following response pertains specifically to Indiana, similar programs are

offered in other states.



Regional workshops are conducted throughout Indiana. The majority of higher education institutions conduct inservice training programs. Projects WILD and LEARNING TREE have reached over 20,000 teachers with hands-on workshops. Hoosier Association of Science Teachers, Inc. (HASTI) designs a special block of environmental education each year during their annual conference. The Environmental Education Association of Indiana (EEAI) reaches 200 teachers each year during the annual conference. Regional education service centers also conduct workshops.

Joe Wright, Environmental Science Consultant, Indiana Department of Education.

Notes from the literature



The experience that teachers gain from hands-on learning opportunities has important benefits. A hands-on activities course which promoted social interaction lessened student-teachers' science anxiety and increased content knowledge (Hall et al., 1989).



Videotapes are an effective way to show teachers appropriate methods for using a science kit (Winnett, 1988).



Universities frequently hold preservice and inservice workshops. For example, the University of Miami held summer workshops entitled "Teaching Science With Toys" (Taylor, Williams, Sarquis, & Poth; 1990).



Hands-on science museums may be an effective way for teachers to get experience with hands-on learning (Ault & Herrick, 1991).

5. *Where do I find resources to develop hands-on activities?*

Teacher's Response



In my own experience, I generate lab activities based upon ideas obtained by four different means. A primary resource for developing hands on activities has to be textbooks. I have a tendency to stockpile old physical science textbooks and peruse them for ideas on labwork. In a similar vein, the reading of science periodicals and NSTA publications [*Science and Children*, *Science Scope*, and *The Science Teacher*] will also lead to generation of hands-on activities.

A second resource I use to develop hands-on activities is other teachers. Almost all teachers have some original ideas or have read some resource you have not. Failure to tap into the minds of your peers would have to be considered one of the original sins of teaching.

A third means of developing lab activities is the use of currently used activities. I have found far too many lab activities where students only superficially analyze what they have investigated. In rewriting interpretations to include more critical thinking skills, students end up hypothesizing on related questions and topics. Many of these types of questions have led me to design related labs to an original lab.

A fourth resource I use to develop hands-on activities is the students themselves. No matter how long you teach, students will continue to ask questions that you have never been asked before. Since all labwork is based upon finding answers to questions, students may design labs themselves based upon these questions. In many instances we have designed labs in class by collecting data and manipulating variables.

Larry Dutcher, Hixson Middle School, Webster Groves, MO

Developer's Thoughts



Say you want to teach a life science unit organized around the half dozen microscopes purchased from last year's special funding. You consult your *TOPS Ideas* catalog and find a few related lessons on *Light*, but otherwise come up dry. What should you do next?

Because all hands-on activity involves materials, your next step is to pull together anything related to microscopes (even remotely) and place it on a designated table. Go on a nature scavenger hunt with your class. Ask your students to bring small things of interest from home. Add everything that turns up to your table collection. Then ask each student to focus on one particular object. Examine it through a microscope, of course. Write about it. Draw it. Design an activity to teach someone else something new. Swap activities. This sort of unstructured messing about is not for the uninitiated. It will generate confusion and noise to be sure. But for you veteran teachers skilled at pulling order out of chaos, the results are rewarding. Not only will you foster creativity and problem solving skills, [but] you will also generate a wealth of microscope activities using materials you already have!

You can, of course, mess about with your own table full of materials at home, then bring a collection of more organized activities to school. (As a curriculum developer, this is what I do all the time.) Either way, the same important principle holds: assemble materials first. Creative, inexpensive ideas will follow, more wonderful than you ever thought possible.

Ron Marson, TOPS Learning Systems, Canby, OR

Notes from the literature



Identify the four to eight major science topics that you teach at a grade level. Start a filing system of activities based on these major topics (Kotar, 1988).



NASA frequently publishes educational materials that contain ideas for developing hands-on activities. In *Rockets: A teaching guide for an elementary unit on rocketry* (Vogt, 1991), there is factual information on rockets followed by ten hands-on activities utilizing inexpensive materials. These and other NASA publications can be found by contacting regional teacher resource centers or by using the ERIC database. ERIC is short for Educational Resources Information Center, a federally funded system that has developed and maintains the world's largest educational database. You can search the database for materials in a variety of ways, and most of the materials in the database can be obtained in printed form. For more information, contact a reference librarian or call 1-800-USE ERIC.



Activities can also be developed from studying proven programs. *Promising and Exemplary Programs and Materials in Elementary and Secondary Schools-Science* lists many activity centered programs (Helgeson, Howe, & Blosser, 1990). *Science Education Programs that Work* has compiled a collection of exemplary hands-on programs. These programs include: "Hands-On Elementary Science"; "Life Lab Science Program"; "Starwalk"; "Stones and Bones: A Laboratory Approach to the Study of Biology, Modern Science, and Anthropology"; "Wildlife Inquiry Through Zoo Education (WIZE)"; and "Jeffco Life Science Program" (Sivertsen, 1990). Teachers can read the descriptions of programs and materials and evaluate their appropriateness for their classes. Activities can be modified to meet their students' needs.



"A resource book of activities that have been tried and found successful, perhaps modified many times from experience, can be a wonderful thing to have on hand. Good sourcebooks do, in fact, enable most of us in teaching to pinpoint relevant exercises quickly, to challenge individuals or groups of students more engagingly, and offer us useful primary or supplementary learning experiences. Often they provide relief from the

constant drain of inner resources, and at other times, good sourcebooks stir our own creative powers to invent, with a particular idea or child in mind" (Pines & Pines, 1981). Pines and Pines go on to say, however, that there are dangers inherent in over-reliance and improper use of sourcebooks. Many valuable sourcebooks and activity guides are available from the National Science Teachers Association and the ERIC Clearinghouse for Science, Mathematics, and Environmental Education.



A particularly useful sourcebook for identifying human resources is the *Sourcebook for Science, Mathematics & Technology Education*, which is revised annually and published by the American Association for the Advancement of Science. The authors say, "We want the *Sourcebook*...to be the first place you look when you need information about science, mathematics, and technology education" (Calinger & Walthall, 1990). The book includes over 2,000 entries regarding specific programs, publications, and organizations, including the coordinators for the Dwight D. Eisenhower Science and Mathematics Education Program.

6. How is hands-on learning evaluated?

Teachers understand the importance of evaluation and are expressing concern (Symington & Osborne, 1983). Evaluation is important in hands-on instruction to assess learning in students, to discover misconceptions developed by students, and to determine the effectiveness of programs (Doran & Hejaily, 1992). "As classroom teachers, we can praise hands-on experiential science, but until we can demonstrate that students are learning significantly more of the fundamental thinking skills of science, we cannot say that they have truly achieved science literacy" (Tetenbaum, 1992).

Teacher's Response



Hands-on learning in my classroom is evaluated by having the students tell me why certain events or situations occurred. If the proper answers are not given, I continue to ask more questions about the experiment and I give them clues as we go to help them figure out the answer....Then I ask for volunteers to restate in their own words the concepts that we discovered. Finally, I ask questions at random to check one more time if they learned the objectives of the class.

Bertha Vargas, fourth grade teacher, Gertrude M. Bailey International School, Lowell, MA

Developer's Thoughts



To determine if a student is able to do science, he or she must engage in performance-based assessments. In this context the student works with materials to answer questions. The assessment must be designed so that the answers can not be obtained by any other means. The materials used should be familiar to the student, but the context should be fresh. If one is assessing the ability to measure length, the student should be asked to discover the length of an object that he or she has not seen before. A good response on the part of the student would be to select a familiar meter tape and use it properly to measure the length accurately....To determine if a student is able to communicate adequately a series of questions are asked that require the use of the vocabulary and discussion of the concepts developed in the science activities.

Larry Malone, Full Option Science Program (FOSS) Co-director, Lawrence Hall of Science, Berkeley, CA

Notes from the Literature



"The problem of assessment also constrains the spread of 'hands-on' science. It is relatively easy to test children's knowledge when they have been asked to memorize lists of data from a text. It is much harder to design tests that measure learning derived from direct experience....The challenge before science educators is to develop better means of measuring both factual knowledge and the kinds of understanding students acquire through activities. When that task is accomplished, a major roadblock to science achievement will have been removed" (William J. Bennett (as U.S. Secretary of Education), 1986, p. 28).



"A behavioral objective for a task helps focus the specific skills and materials and helps to establish scoring parameters." Performance tasks for skills should not be paper-and-pencil items, but should involve students in doing activities. The directions must be clear and concise; diagrams can help with clarity. Questions should be based on the process skills identified. For example, "Write your observations for..." or "Predict what will occur when..." In developing a scoring system, performance and not content should be stressed as the most important aspect contributing towards a grade (Doran & Hejaily, 1992).



Keep the performance items direct and simple, and not too long. Provide diagrams and clear instructions. Use materials which are familiar to the students. Remember to consider the manageability of the item with a classroom full of students. Develop a scoring rubric

before having students complete the assessment. Discuss the scoring system with other teachers and try for consensus on how to award points (Finson & Beaver, 1992).



Observational checklists are easy and flexible assessment tools. For instance, to measure a student's ability to draw conclusions the following scoring rubric could be used:

<u>Points</u>	<u>Characteristics</u>
0	Fails to reach a conclusion
1	Draws a conclusion that is not supported by data
2	Draws a conclusion that is supported by data, but fails to show any evidence for the conclusion
3	Draws a conclusion that is supported by data and gives supporting evidence for the conclusion (Nott, Reeve, & Reeve;1992).



"At the elementary school level especially, but continuing throughout school and beyond, informal investigation is an important part of 'hands-on' science....The teacher's evaluation of such activities is also likely to be informal, relying mostly on unobtrusive observations. Teachers may find it useful to observe systematically individual students, small groups, or even the class as a whole. The teacher's observations should be recorded in writing, either immediately or at the end of the day, noting the time, date, and activity. These remarks may be quite brief, even cryptic, but should specify in some way what was seen, not just the teacher's judgment of its quality. If the comments are recorded on index cards, say, they can be filed easily by student name, can serve as a record of progress and attainment to be used in planning further instruction, shared with parents, used in grading, and perhaps even shared with the students themselves" (Haertel, 1991, p. 241).



Portfolios are increasingly becoming an important tool in science teaching and learning. A portfolio is a collection of documents that contain evidence of achievement. Evidence presented in the portfolio may be worksheets, laboratory reports, raw data, first drafts, or diagrams of laboratory equipment. It is very important that the evidence is meaningful to the students and it is recommended that students attach captions to each entry and state what the evidence is and why it is evidence (Collins, 1992).



"The development of portfolios allows teachers and students to work and learn together; provides opportunities for reflection and self-assessment; helps redefining traditional student and teacher roles in relation to the science curriculum; emphasizes the culture in which teaching and learning occurs; and empowers both students and teachers with respect to science learning" (Tippins & Dana, 1992).



Other assessment techniques include group discussion, concept mapping, and student interviews (Gaffney, 1992). Some assessment task should be done by student teams to help build group skills (Small & Petrek, 1992). It is often beneficial to have students score their peers' group work (Culp & Malone, 1992).

7. What are some strategies for helping students work in groups?

"The teacher, acting as the director of research, with students working as science-research teams always has been a great way to teach science" (Small & Petrek, 1992). However, helping students to work in groups is a definite concern of teachers. It is crucial to science learning, developing social skills, and facilitating classroom management.

Teacher's Response



1. Decide the size of the group. I typically use from two to six students, depending on the nature of the task and the time available.
2. Assign students to groups, preferably by your heterogeneous grouping rather than by student ability or student self-selection. Do not change group assignments with each new task, rather allow time for each group to get to know each other through the work of several tasks. I may change grouping as little as once a month.
3. Arrange the room so that groups can work together without disrupting other groups.
4. Plan instructional materials to promote interdependence. Give only one copy of the materials to the group.
5. Assign roles to assure interdependence. I give job titles such as summarizer, researcher, recorder, encourager, and observer.
6. Structure individual accountability as well as a group assessment in which individuals' rewards are based both on their own scores and on the average for the groups as a whole.
7. Discuss desired behaviors. Request that students take turns, use personal names, listen carefully to one another, and encourage everyone to participate.
8. Monitor student behavior. Circulate around the room to listen and observe groups in action. Note problems in completing assignments and working cooperatively.
9. Allow opportunities for groups to orally report their findings to the whole class.
10. Give feedback to each group about how well the members worked with one another and accomplished tasks and how they could improve.

Sally Parker, Brentnell Alternative Elementary School, Columbus, OH

Developer's Thoughts



First of all, the room environment can be constructed so that it fosters the cooperative-learning approach. Instead of putting desks in rows, put them together to make laboratory tables. Or better yet, get rid of most of the desks and put in tables. Also, there are many group-learning activities that can be done in a "different" academic setting that will enable students to learn how to work together....Doing science experiments is more fun in a group, even in a twosome, because you can share equipment and knowledge, learn how to make charts and graphs together, discuss the outcomes of the experiments, and come to conclusions together. The teacher can also suggest roles each member of a group can play such as one person reading the instrument, another recording the data, another physically starting the experiment, etc.

Dianne K. Hyer and Roger C. Eckhardt, Students Watching Over Our Planet (SWOOPE), Los Alamos National Laboratory

Notes from the literature



"If we expect students to work together, we must teach them social skills just as purposefully and precisely as we teach them academic skills" (Ostlund, 1992).



There are three categories of social skills: cluster skills which help students form groups, task skills which help students accomplish their goals, and camaraderie skills which help group members like each other. In developing social skills stress one at a time. The teacher should model, explain, and elicit examples of appropriate behavior for the skill. For example, in promoting the skill of involving all group members in an activity, students in a group can be given different color chips. When they encourage another student to participate they can place their chip in a pile. At the end of the activity, the number of chips contributed by each person can be counted to determine how effective they were in using this behavior (Ostlund, 1992).



When teachers intervene to assist working groups, even when requested by students, the intervention usually ends with the teacher giving directions. The intervention produces far more teacher talk than student talk (Oakley & Crocker, 1977).



It is important not to give too much guidance and to do too much for the students. In a case study of a teacher attempting to implement a hands-on, problem solving approach, Martens (1992) found that the teacher's desire for students "to get the right answer" produced teacher behaviors which eliminated opportunities for problem solving. Helping students

work in groups is important for science learning. Skills should be taught to the students. When students are actually working in groups, teachers should resist the temptation to jump in too early and put the students on the right path.

8. How does or should the use of hands-on materials vary with age?

Teacher's Response



In the early childhood (ages 4-7) years, the *process* of exploring, experimenting, and inquiring should be the major emphasis. The language association should be primarily oral.

In the middle years, the process of inquiry should be followed, rather than preceded, by writing/ reading experiences.

Ruthanne McCarthy, kindergarten teacher, Gertrude M. Bailey International School, Lowell, MA

Developer's Thoughts



There is no student too old for hands-on activities. Teachers, senior citizens, etc., still enjoy learning and participating through activities. The type of activity will vary with age, from observing, exploring, and manipulating tangible objects and places at young ages, to thinking about and trying out planned events at upper elementary, to manipulation of data, maps, and remote images in high school. There is a period in which activities are not cool (grades 8-9, 12, and middle age ...), but seniors who go to elder hostels and nature summits, etc., love to get involved in their own learning. Isn't it sad how some people don't let themselves participate because they don't want to seem unsophisticated or they think they can learn just as much by watching others?

Rosanne W. Fortner, The Ohio State University School of Natural Resources, producer of Ohio Sea Grant Education materials and Project JASON curriculum activities

Notes from the literature



Several research studies have been done to try to determine how teachers are using hands-on science. Harty, Kloosterman, and Matkin (1989) surveyed elementary school principals and concluded that teachers in the upper elementary grades have more science manipulatives than teachers in the lower grades. Teachers at the lower elementary grades

spend 70 minutes per week on hands-on science teaching as opposed to the upper elementary teachers who spend 90 minutes per week.



Manipulatives are used to teach science more frequently in grades 3-5 than in grades K-2, and problem-solving was given greater emphasis in grades 3-5 than in grades K-2 (Kloosterman & Harty, 1987).



The use of hands-on science appears in junior and senior high schools, although to a smaller extent than in the elementary schools. For example, in the NAEP report card 44% of seventh grade students and 40% of third grade students reported not having done any experiments in the previous month (Mullis & Jenkins, 1988).



"Elementary school experiences are important for establishing understanding of science concepts and developing needed skills for further learning" (Howe, et al., 1990, p. 33).



The importance of the early use of hands-on learning has been long recognized. "The study of both plants and animals should begin in the lowest grades, or even in kindergarten. One object of such work is to train the children to get knowledge first hand. Experience shows that if these studies begin later in the course, after the habit of depending on authority- teachers and books- has been formed, the results are much less satisfactory (National Education Association, 1893, p. 139).



Hands-on elementary science curricula can assist children in making transitions from one Piagetian level of thought to the next (Kren, 1979).



The earlier teachers emphasize the concrete, sensual aspects of science, the firmer the foundation will be for science learning. However, no matter what the age of the student, "experiences form the basis of real learning. Early in any science lesson, your students should begin their hands-on experiences. Save the vocabulary words and textbook reading activities for later as reinforcements of the lessons the students have already learned firsthand" (Kotar, 1988, p. 40).

9. *Hands-on science can be expensive. How do I get materials and equipment?*

Inadequate science equipment is an obstacle to hands-on science teaching that has existed since the 1970s (Tilgner, 1990). Morey (1990) found that a lack of materials is the most reported major obstacle in elementary science education. Numerous other studies have found the lack of hands-on

materials to be a major problem for teachers (Finan, 1990; Guerro et al., 1990; Hendry, 1988; Glass, 1984).

Teachers' Responses



To teach hands-on science to middle school sixth-graders in a rural school district, where lab equipment is scarce to nonexistent, requires dedication and innovation on the part of the classroom teacher. It can be done. To teach body systems to my sixth-graders I have a very understanding butcher who supplies me with all of the hearts, lungs, kidneys, brains, eyes, and other organs that we are studying free of charge. The students are able to handle, dissect, and examine tissue from these organs to get a much better understanding of living body tissue and its function. These labs fuel a fire that no textbook or black and white film from the 1950s could even spark.

In physical science I can make 15 sets of gram weights from nuts, bolts, and other items from my local hardware store. I can make graduated beakers from empty jelly jars and mark them with a permanent marker. I can make a balance from pegboard, a nail, a piece of soda straw, and scraps of wood. The materials and equipment you can design for this age group to foster an early interest in the sciences is only limited by the teacher's imagination and dedication to their subject area.

Saundra K. Elsea, Sixth Grade Science/Health, Kingston, OH



If my school has monies I just ask my principal and if he has funds I have no problem. If money is not to be found I ask the children to bring in materials from home. As a last resort I simply buy the materials with my own funds. At times we have done fund raisers for field trips and that could be another source for materials.

Dave Kelly, Sixth Grade Teacher, Daley School, Lowell, MA

Developers' Thoughts



In some cases you can get materials and equipment from people who have them: research people. Contact corporations in your area to ask them to consider you when they are discarding materials. You can acquire some very nice, albeit used, equipment. However in many cases you need 25 of the same object, and you cannot expect to have it donated in that quantity. You must raise the money. Find out whose father or mother is an engineer, scientist, or medical doctor. Impress them with your need and ask them to call a

few other parents to make a contribution. I did that last year and raised over \$400 with a dozen phone calls (and only one turn down).

For bigger projects, local companies and foundations may contribute. They are out there; you need to find them. See if your community has a volunteer center or a community foundation. They can help you find the sources. The library may also have the information.

Edwin J.C. Sobey, National Invention Center, Akron, OH



Hands-on science programs that start with what you already have (or can easily obtain) are naturally cheap - perhaps \$10 to \$15 per student per year. If your school doesn't budget for science materials, you can order many items out of general supplies. Here at TOPS we occasionally get orders paid by the PTA.

Ron Marson, TOPS Learning Systems, Canby, OR

Notes from the literature



Elementary school classrooms are a little more likely to have commercially available science manipulatives than they are to have teacher-assembled materials (Harty, Kloosterman, & Matkin; 1989). However, there are many sources of information for teacher-assembled materials.



Many low cost, educationally sound hands-on activities can be found in science education magazines. For example in *Science Activities*, Philips (1992) described how readily available equipment can be used to teach principles of the controlled experiment. The National Science Teacher's Association produces *Science and Children* (elementary grades) and *Science Scope* (middle grades) which contain a plethora of inexpensive, creative science activities. For example, in "Can-Do Science" in *Science and Children*, Scott (1992) describes different hands-on activities that can be done with ordinary cans. These and other activities can be located by using the ERIC database, as described on page 12.

10. Where do you keep materials and equipment once you get them?

Extensive hands-on science programs often involve much material, and therefore, storage and organization can be a problem. Teachers are concerned with their ability to organize and maintain these materials (Finan, 1990; Symington & Osborne, 1983).

Teacher's Response



My classroom has standard kitchen base cabinets around half the room and seven large (7' by 4') cabinets which are 18 inches deep. The large cabinets are equipped with hasps and padlocks. There is no chemical storage cabinet but I have only household chemicals which are kept in the locked cabinet. All materials are in the science room. There is only one 7th and 8th grade science room in the building.

Phyllis Frysinger, Miami View Elementary, S. Charleston, OH

Developer's Thoughts



You may think that materials lists are boring. But they are the bedrock. Materials define the content, economy and ultimate success of any hands-on science program. Here's my list; color it basic.

CONSUMABLES

paper clips
masking tape
wooden spring clothespins
steel straight pins
aluminum foil
rubber bands (all sizes)
straws

NONCONSUMABLES

Scissors
test tubes (large and small)
wall clock or wristwatches
meter sticks
oil-based modeling clay
eyedroppers/ with bottles
graduates (10, 100 ml)

RECYCLEABLES

jars with lids
medium cans
Styrofoam egg
cartons
plastic produce
bags
soda bottles

[Note. Only a sample of the complete list is presented. Contact TOPS learning systems for more information.]

I use these materials over and over again to teach the 700 or so hands-on science lessons that I have developed at TOPS Learning Systems. I organize these simple things on open shelves in labeled boxes, jars and cans. When I teach about animals, or plants, or light, or sound, or rocks and minerals, 80-90% of what I need is already right at hand.

The remaining 10-20% of unlisted materials are specialty items I store in the closet. My *Animal Survival* box contains tempera paint for camouflage. My *Green Thumbs: Radishes* box contains radish seeds and potting soil left over from last year's unit. Mirrors and colored cellophane are in my *Light* box, tuning forks in my *Sound* box, and egg-carton rock collection in my *Rocks and Minerals* box.

Ron Marson, TOPS Learning Systems, Canby, OR

Notes from the literature



Materials can be kept in bags. Combining a book with hands-on material in a bag creates interesting activities. The large sealable food bag should contain all of the necessary materials and a card with step-by-step instructions. A hole in the corner of the bag can be used to hang the bag on a peg or bulletin board (Carlile, 1992).



Cans can be used both for conducting science activities and storing activities. The activity cans can be stored in a large metal trash can (Scott, 1992).

Final Comments

The information presented in this document was gathered by contacting teachers and consultants who promote hands-on approaches to science teaching, by talking with curriculum specialists and developers who design programs and materials for active learning, and by reviewing the professional literature related to hands-on teaching and learning. Broad support for hands-on methods clearly exists, but there are also crucial questions to be answered by anyone or any group planning to enrich their classrooms with a more activity-based, inquiry-oriented approach to teaching. As the responses to questions presented here indicate, none of the crucial questions are as simple as they first appear, and different educators have different concerns and priorities relating to each question. Perhaps the crucial first step in developing a hands-on teaching style is to acknowledge the open questions and begin a process of finding personally satisfying answers.

The questions and answers offered here will help start the process of self-improvement or school-based reform, but they will soon have to be supplemented by questions and answers of more immediate concern related to local conditions, priorities, and concerns. Hands-on advocates should consider doing what we have done to develop this document; survey stakeholders to generate a list of their questions, then speak with colleagues and specialists about possible answers, and study the professional literature. There are many resources that facilitate access to the reservoir of professional knowledge, so reformers should make a serious attempt to find out what others already know before investing too much time in formulating personal answers to questions. In addition to the ERIC system mentioned on page 12 and the several sourcebooks cited, there are many online databases and electronic bulletin boards waiting to be used. The authors, in fact, used electronic bulletin boards and mail services to communicate with several of the contributors to this document. For a comprehensive listing of available resources, refer to the *Directory of Online Databases* (Marcaccio, 1992).

Most importantly, keep asking questions, and consider the full range of answers that colleagues offer.



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Other Useful Addresses

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